MATRIX METHOD FOR ESTIMATING THE SOUND POWER RADIATED FROM A VIBRATING PLATE FOR NOISE CONTROL ENGINEERING APPLICATIONS

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***Abstract*— Vibrating plates may become strong sources of unwanted sound exposing humans to high levels of noise, particularly at low frequencies. Therefore, knowledge of the sound radiation of vibrating plates is very important for noise control engineering. This paper presents a method to estimate the sound power radiated from a baffled vibrating plate. Instead of using a modal radiation approach, the sound power is expressed in terms of volume velocities of a number of elemental radiators by dividing the vibrating surface into small virtual elements. Thus, the method discussed here is based on the radiation resistance matrix where its entries are calculated by treating each element as a circular piston having an area equal of that of the corresponding element. As practical examples, the method is applied to estimate the sound radiation from guided annular and rectangular plates. Numerical results indicate the accuracy and efficiency of the numerical technique.**

***Keywords*— Plates, Sound radiation, Sound power, Noise control, Numerical methods.**

I. INTRODUCTION

The sound radiation from a vibrating plane structure is of great practical importance in Applied Mechanics and has been an active research subject for many years. In particular, the sound radiation from vibrating plates commonly appears in industry, airplanes, cars, machinery, buildings, and electroacoustical devices. Knowledge of the sound radiation characteristics of these structures is important not only for the researcher who wishes to understand their behavior, but also for the engineer whose duty it is to prevent any harmful noise levels which may occur in the course of the industrial use of such structures.

In recent years, several studies have been committed to estimate the sound radiation characteristics of plates subject to different kinds of excitation and with various boundary conditions. When a plate is excited by an external force its vibration transfers energy to the surrounding fluid medium which is radiated as sound waves.

The basic equation for the calculation of the sound pressure field due to a closed body vibrating harmonically at circular frequency ω, is obtained by a superposition of simple monopole and dipole sources distributed over the surface. This equation is known as the Kirchoff-Helmholtz integral equation (Pierce, 1989; Morse and Ingard, 1986)

$$p(\mathbf{r},\omega) = \iint\limits_S \Big[p(\mathbf{r}',\omega)\frac{\partial G(\mathbf{r}|\mathbf{r}')}{\partial n} + j\rho\omega V(\mathbf{r}',\omega)G(\mathbf{r}|\mathbf{r}')\Big]dS, \tag{1}$$

where $p(\mathbf{r},\omega)$ is the complex sound pressure at a point $\mathbf{r}$ outside the surface, ρ is the fluid density, $V(\mathbf{r}',\omega)$ is the normal complex velocity amplitude at a point $\mathbf{r}'$ on a structural surface of area S, n indicates the outward normal direction perpendicular to the surface, $j=\sqrt{-1}$, and $G(\mathbf{r}|\mathbf{r}') = e^{jkR}/4\pi R$ is the free-space Green's function, where $R = |\mathbf{r}-\mathbf{r}'|$ and k is the acoustic wavenumber. This Green's function is equivalent to the sound field of a simple source in an infinite fluid medium. For a vibrating flat plate set in an infinite baffle, the Green's function satisfies the Neumann boundary condition on the surface and the Green's function equals twice that of $G(\mathbf{r}|\mathbf{r}')$ in Eq. (1). Therefore, Eq. (1) can be written as Rayleigh's second integral (Rayleigh, 1945)

$$p(\mathbf{r},\omega) = \frac{j\rho\omega}{2\pi}\iint\limits_S V(\omega,\mathbf{r}')G(\mathbf{r}|\mathbf{r}')dS. \tag{2}$$

In some cases, Eq. (2) must be evaluated by using the calculus of residues to overcome the singularity of $G(\mathbf{r}|\mathbf{r}')$ when $\mathbf{r}\to\mathbf{r}'$.

Although Eq. (2) has analytical solutions only for a few cases, the Rayleigh integral has been used as an alternative to the finite/boundary elements solution of an acoustic boundary problem. Applications of the Rayleigh integral to calculate the sound radiation from the structural modes of plates having different shapes and boundary conditions, have been reported by several authors (Kirkup, 1994; Wodtke and Lamancusa,